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Lee

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(54) **CYLINDER HEAD AND ENGINE**

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F01P 3/14 (2006.01)
F01L 3/14 (2006.01)

(52) **U.S. Cl.**
CPC ***F01L 3/14*** (2013.01); *F01L 2810/01* (2013.01)

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CPC F01P 3/14; F01P 7/14; F01L 3/12; F01L 3/14; F01L 5/04
See application file for complete search history.

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(57) **ABSTRACT**

To find compromises in the relationship between the component costs of intake and exhaust valves and the downsizing of an engine and the relationship between the cooling performance and the followability of the intake and exhaust valves and coordinate these conflicting relationships as much as possible. A hollow valve encapsulating coolant having a good cooling function is used as an exhaust valve, which is exposed to a higher temperature environment than an the intake valve, to eliminate a disincentive to downsizing. In contrast, a hollow valve that has no coolant, relatively low component cost, light weight, and good followability is used as the intake valve, which does not need to have a better cooling function than the exhaust valve and needs to have better followability than the exhaust valve to improve combustion efficiency.

20 Claims, 9 Drawing Sheets

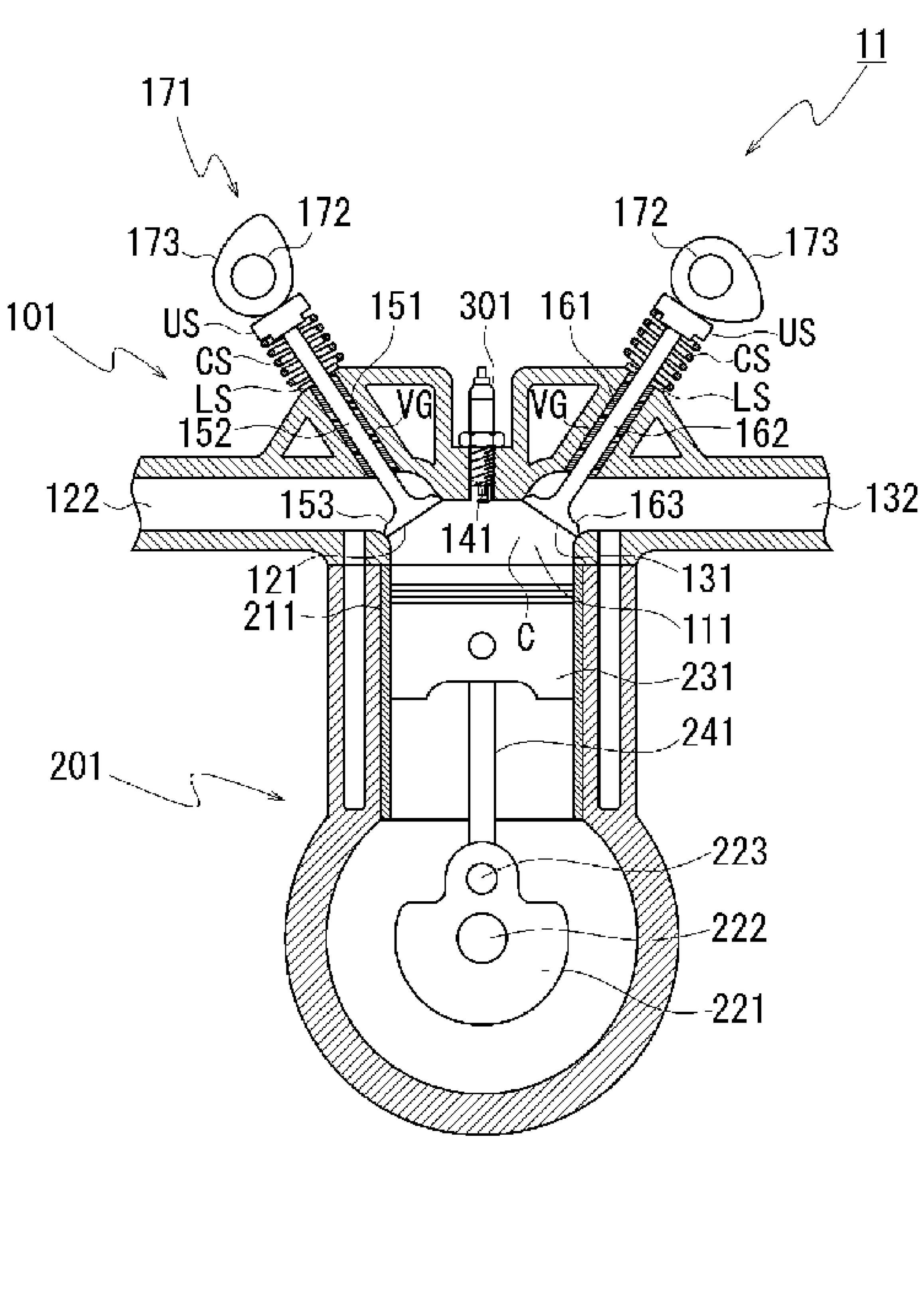


FIG.1

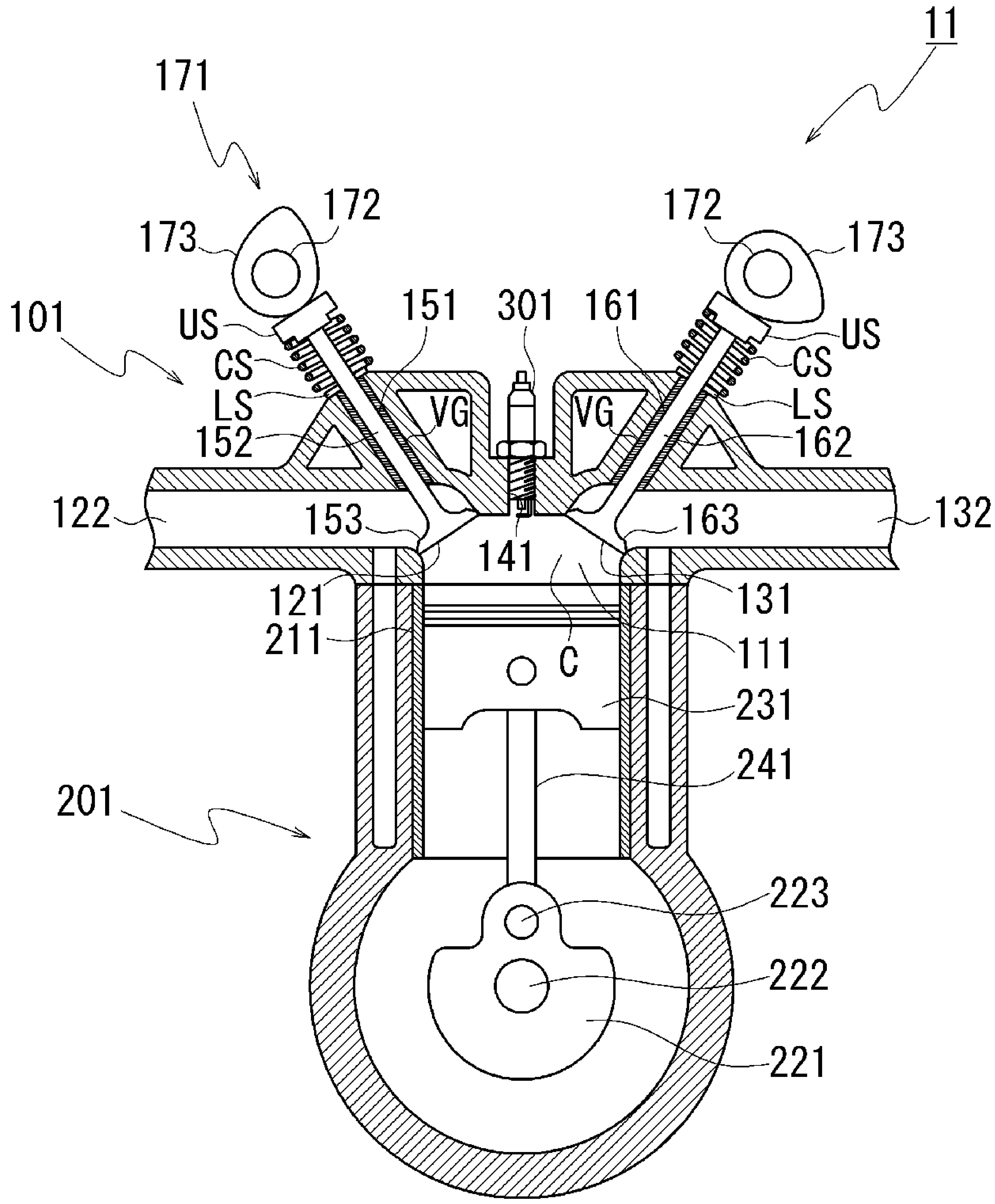

11
171
172
173
172
173
101
US
CS
LS
152
151
301
161
VG
VG
US
CS
LS
162
122
153
141
163
132
121
131
211
C
111
231
241
201
223
222
221

FIG.2

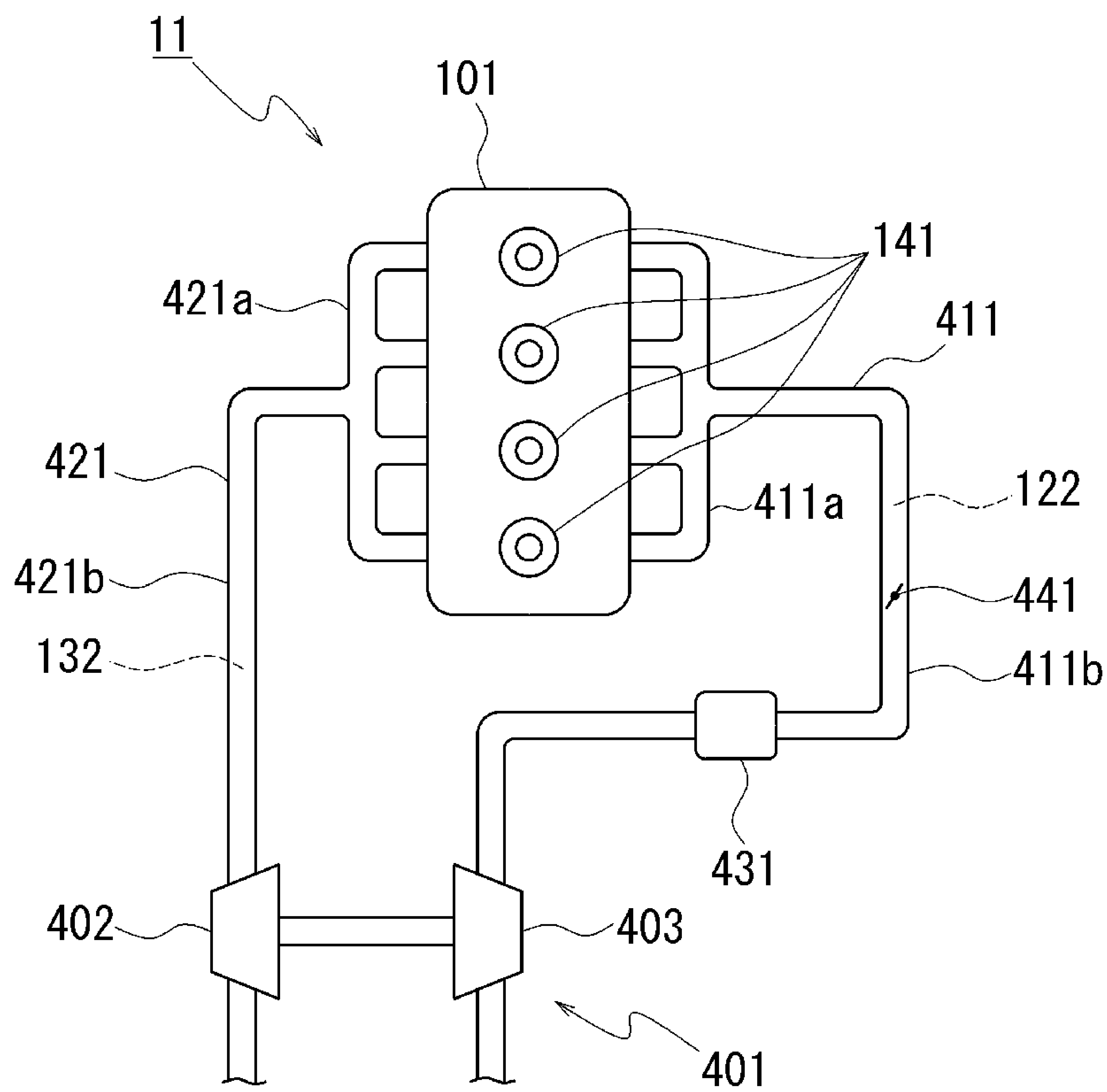

11
101
141
421a
411
421
122
411a
421b
441
132
411b
431
402
403
401

FIG.3

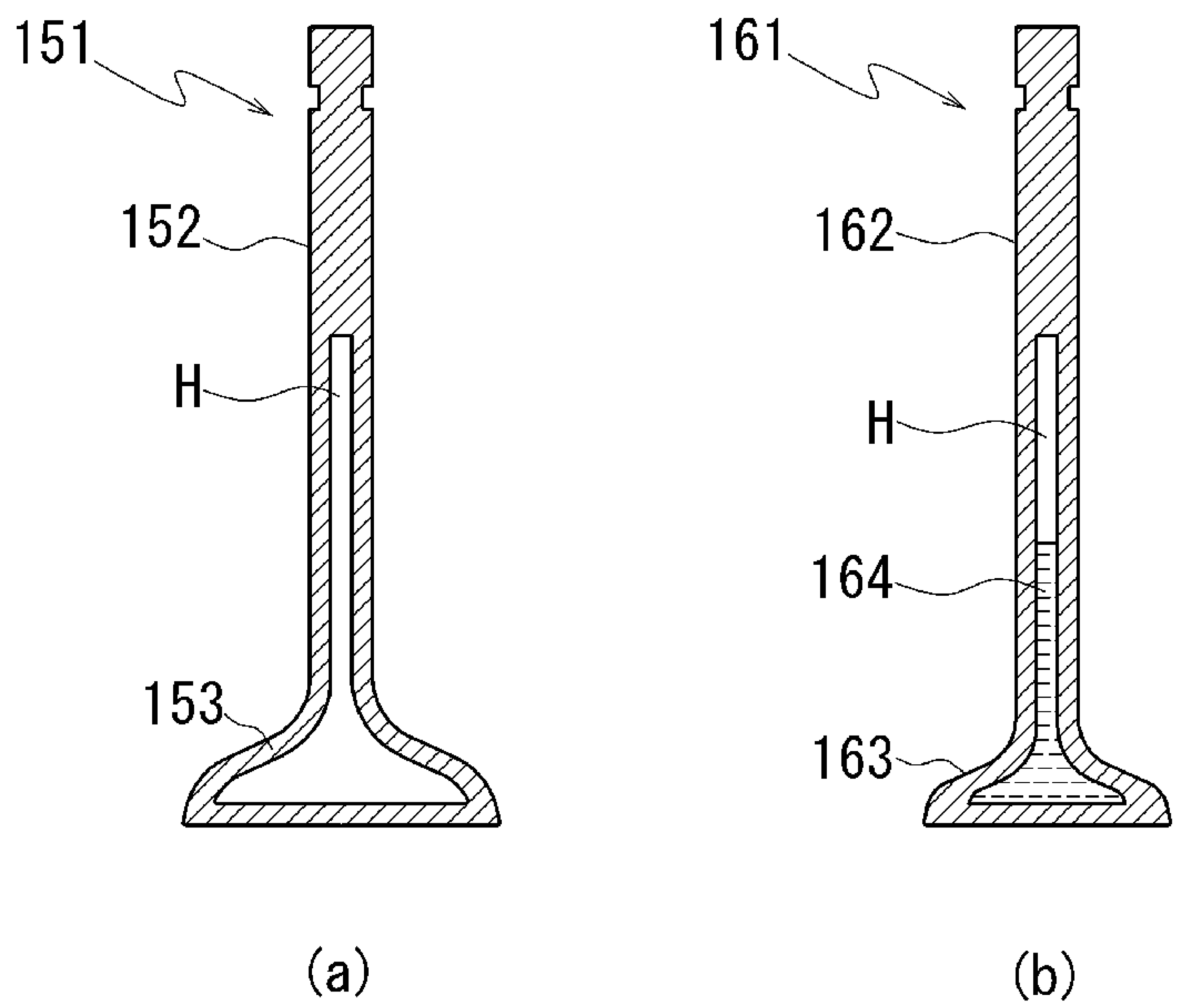


FIG.4

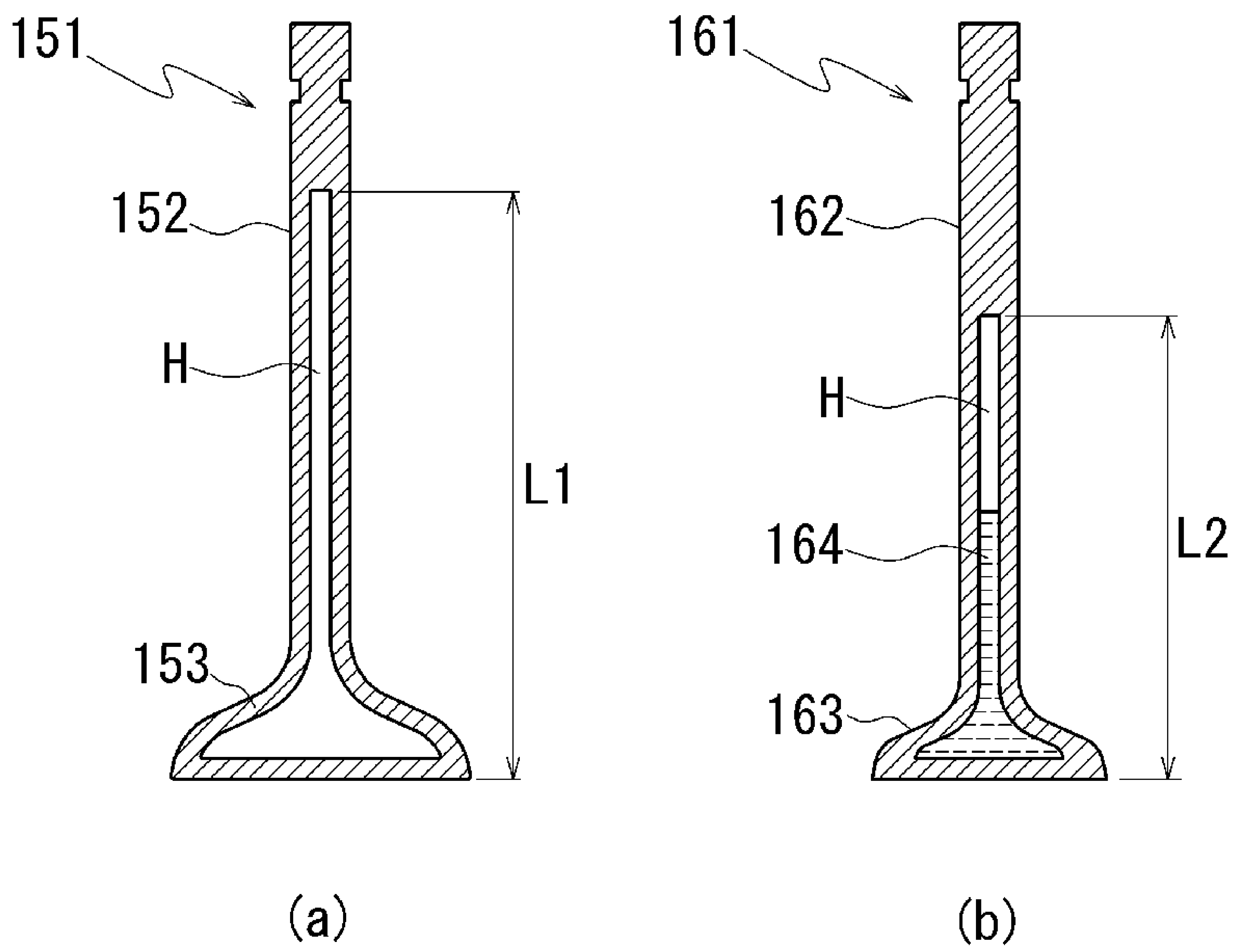


FIG.5

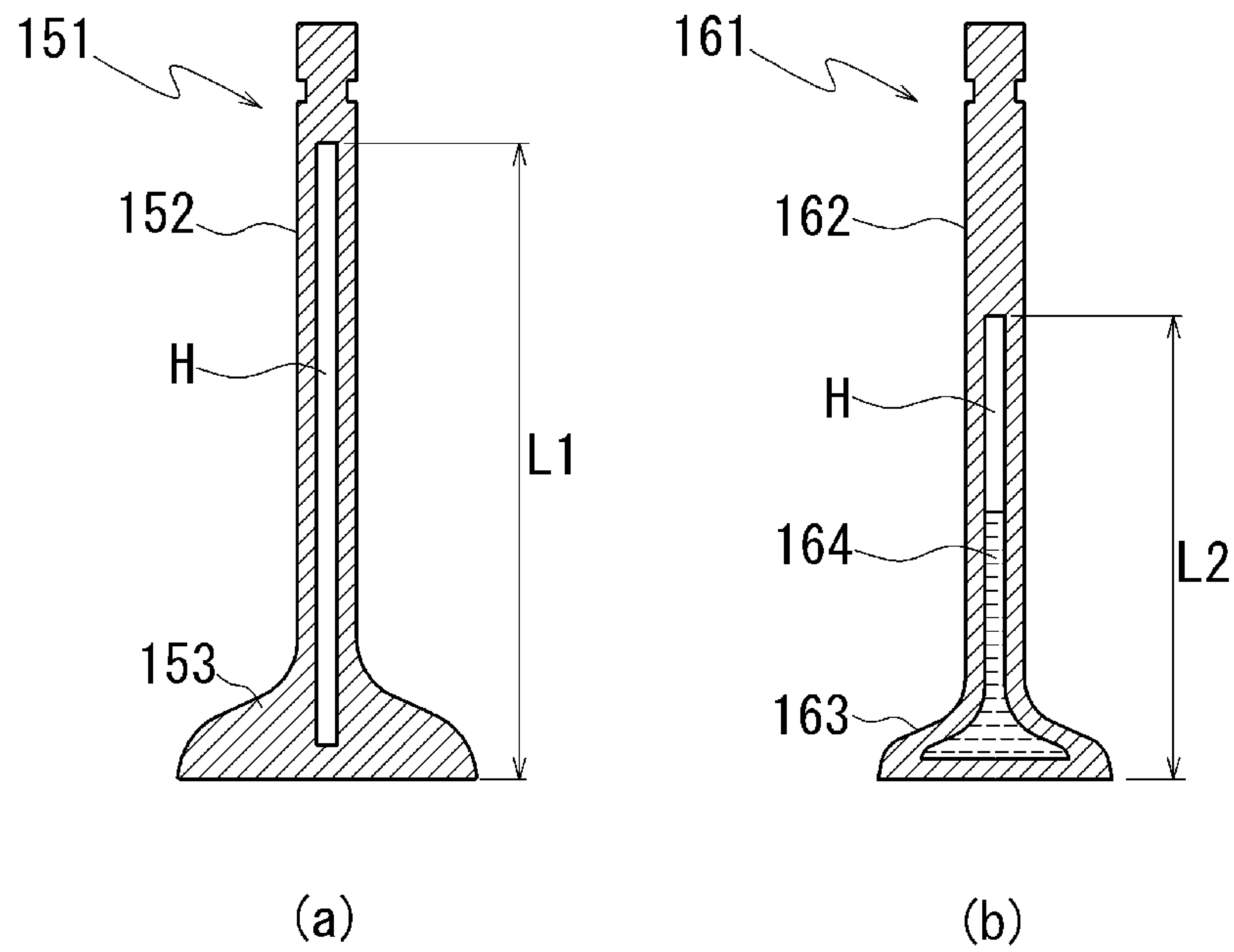
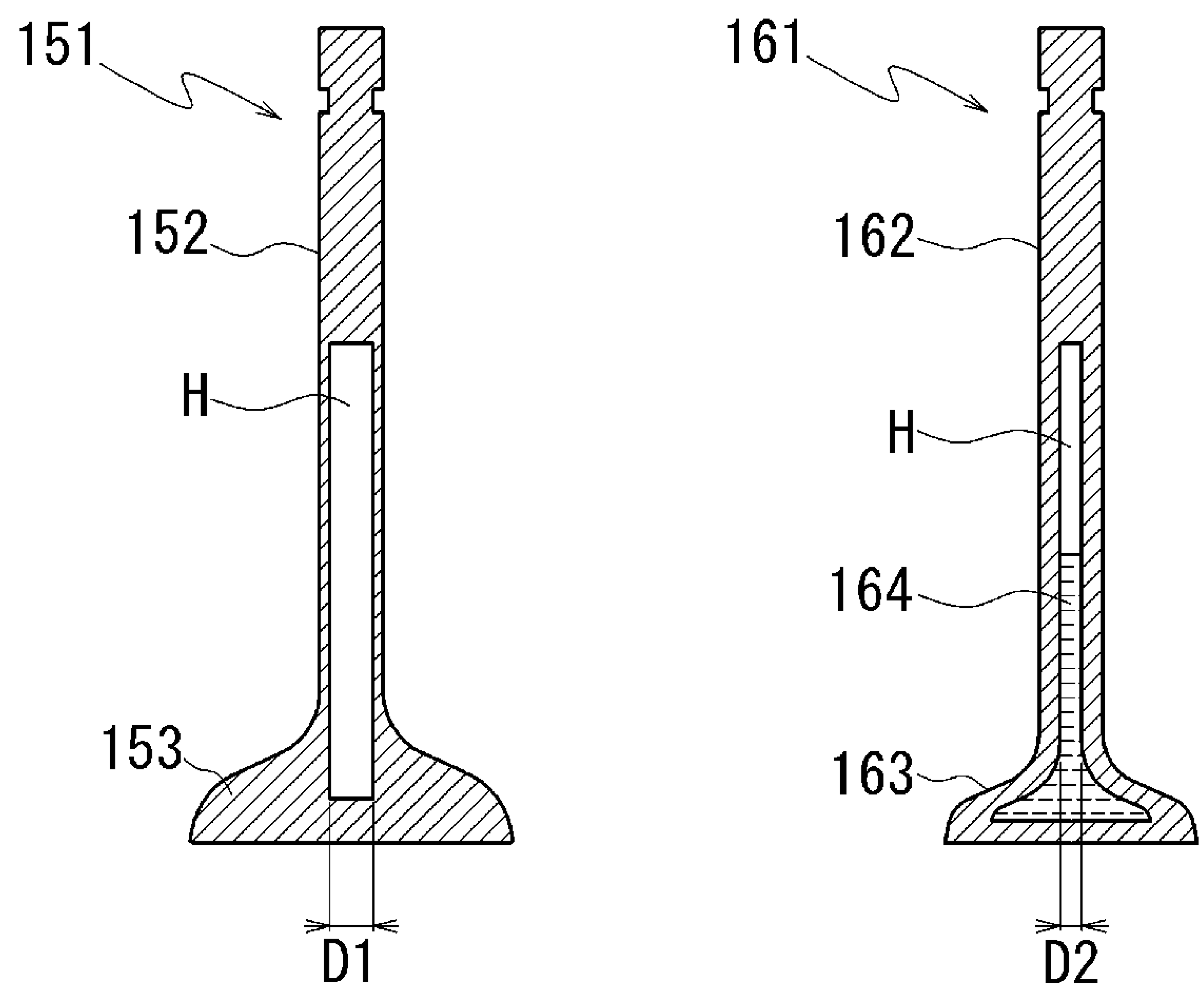


FIG.6



(a) (b)

FIG.7

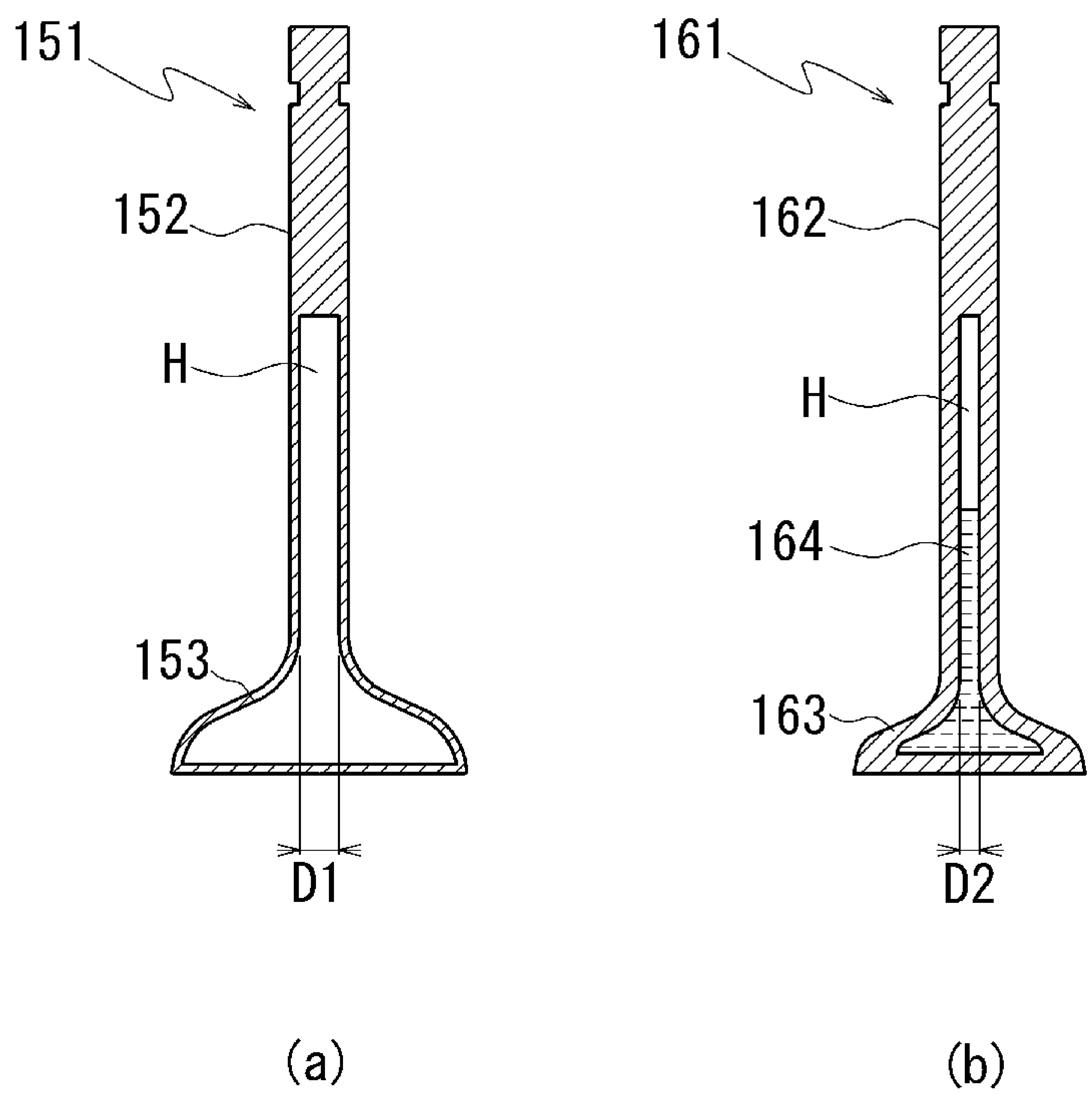


FIG.8

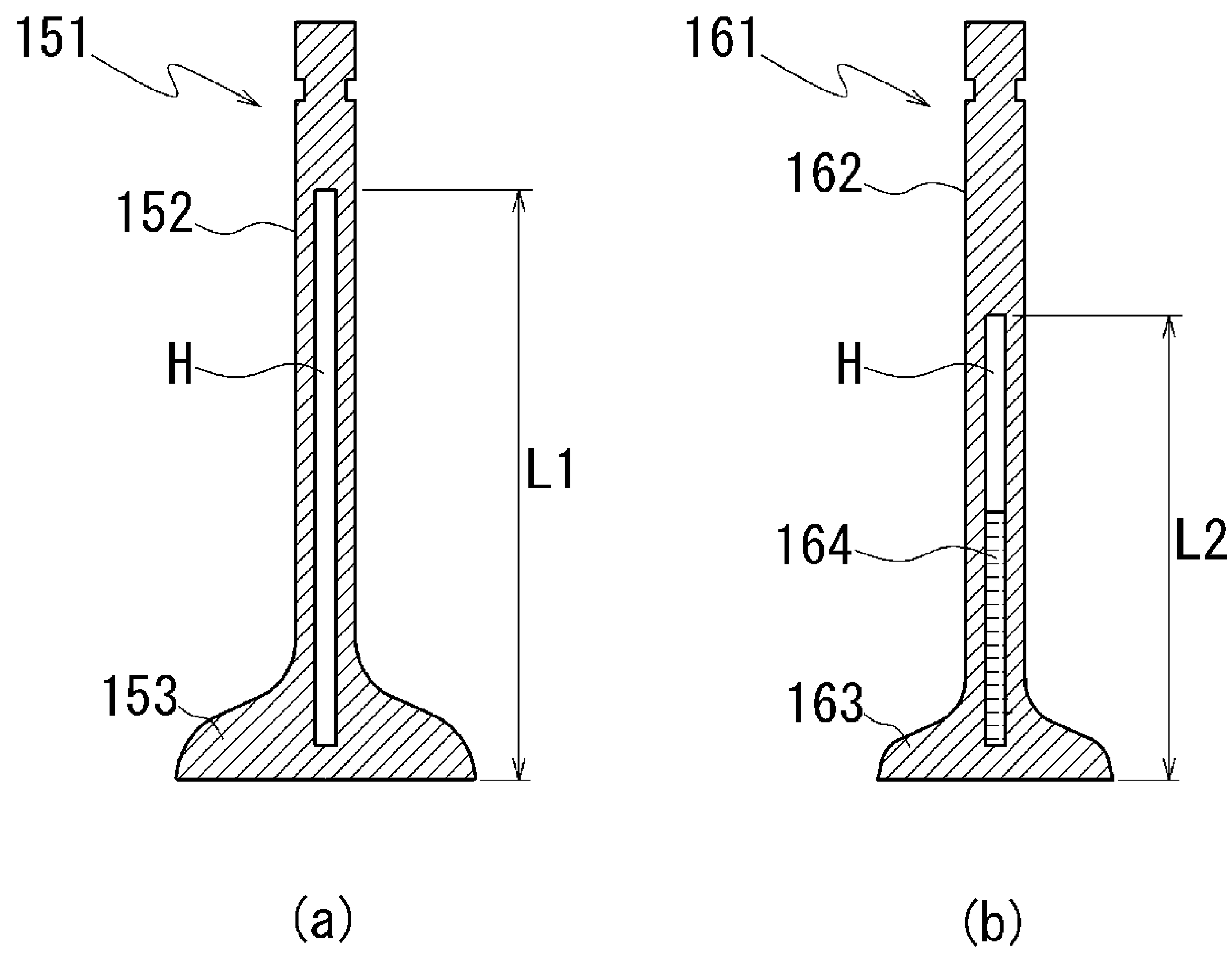
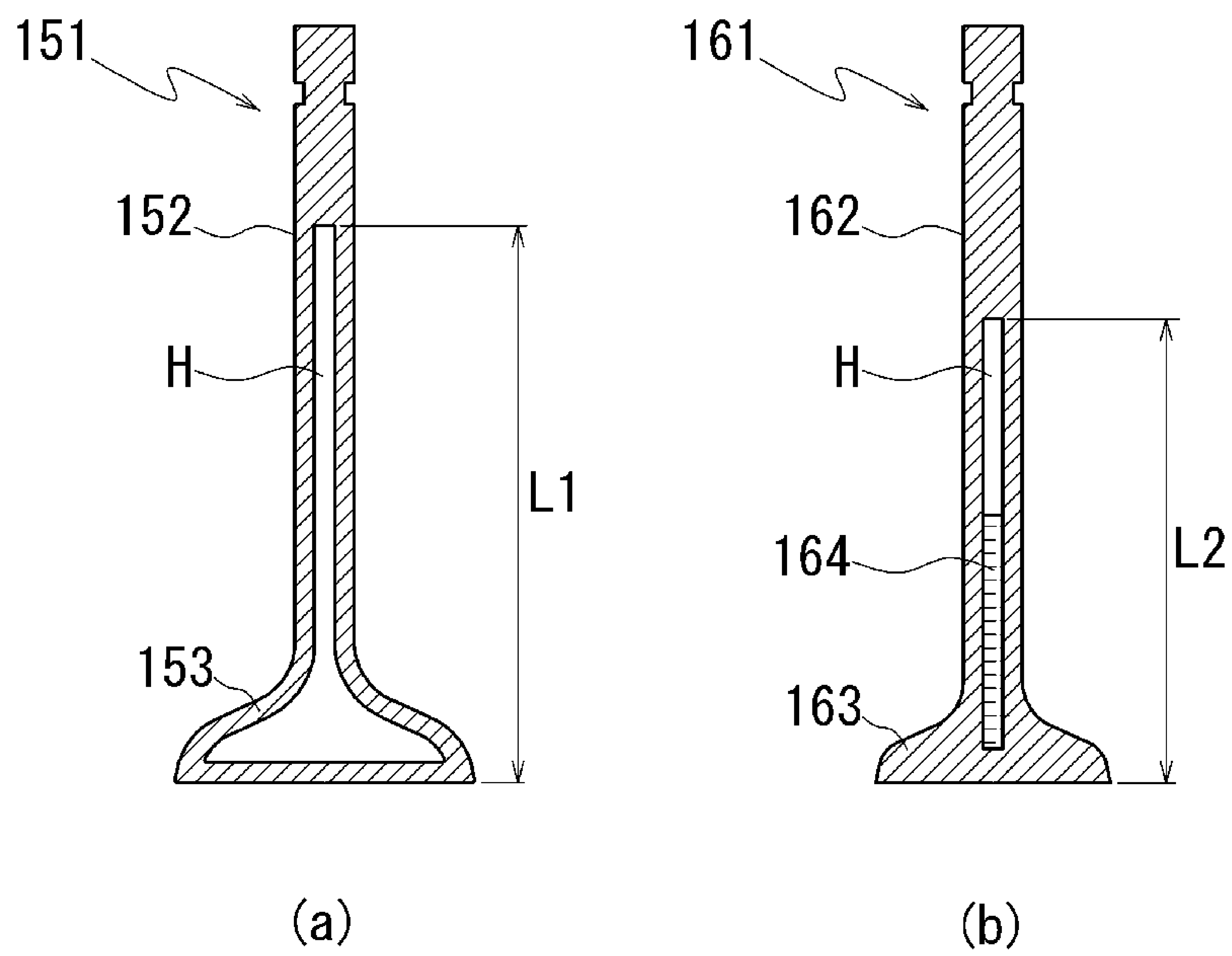


FIG.9



CYLINDER HEAD AND ENGINE

TECHNICAL FIELD

The present invention relates to a cylinder head having hollow valves as intake and exhaust valves and an engine having the cylinder head.

BACKGROUND ART

It is said that the technical know-how of hollow valves for aircraft engines has been accumulated since pre-World War II periods, and hollow valves have been generally used for automobile engines such as, for example, high performance engines for racing cars.

There are two advantages in using such hollow valves.

One advantage is that weight reduction provides high followability, thereby contributing to higher revolution of an engine.

Another advantage is that coolant or the like can be charged with therein because of its hollow structure and cooling effects thereof can be expected. Typically, coolant such as metallic sodium has been encapsulated conventionally so as to support higher temperature of a combustion chamber.

Since such hollow valves requires many manufacturing man-hours and expensive, although introduction to high performance engines for automobiles that have a turbocharger or a high compression ratio was performed in relatively early, a barrier hindering introduction to popular cars was relatively high.

However, from a viewpoint of global warming prevention by reduction in carbon dioxide emissions or the like, downsizing of an engine is a global trend in recent years. That is, there is a trend to adopt an engine having a smaller piston displacement than before even in the same type of automobile, make up for shortage of torque associated with a small engine by installing a turbocharger, and improve fuel economy by increasing the compression ratio.

That is, "downsizing of an engine" does not simply mean reduction in the piston displacement. It also means cancelation of the demerit caused by reduction in the piston displacement or prevention of user's feeling of such a demerit by using methods such as installation of a turbocharger or increase in compression ratio.

Accordingly, in recent years when downsizing of an engine has been widely used, combustion temperature is apt to further rise.

Therefore, attention has been focused on hollow valves and popular cars having hollow valves encapsulating coolant are increasing in number. In addition, engines for light cars have started adopting hollow valves charged with a coolant.

Patents concerning techniques for hollow valves are disclosed in, for example, PTL 1 and PTL 2.

PTL 1 is the publication of unexamined patent application applied on Dec. 24, 1999 and discloses the invention in which a hollow valve is used as at least one of an intake valve and an exhaust valve (see paragraph 0009, FIG. 2, and FIG. 4).

Although the intake and exhaust valves are hollow, charge of coolant is not described.

PTL 2 is the publication of unexamined patent application applied on Oct. 28, 2004 and discloses the invention in which hollow valves are used as both an intake valve and an exhaust valve (see paragraph 0029 and FIG. 2).

The intake and exhaust valves in PTL 2 are different from those in PTL 1 in that the valves charged with a coolant including a sodium compound such as sodium potassium.

CITATION LIST

Patent Literature

PTL 1: JP-A-2001-182540
PTL 2: JP-A-2006-125277

SUMMARY OF INVENTION

Technical Problem

A barrier hindering adoption of hollow valves charged with a coolant is its high component cost. Introduction of hollow valves especially those encapsulating coolant to popular cars is not allowed unconditionally because the component cost increases the sales price.

In contrast, in consideration of tendencies to apply a turbocharger because of downsizing of an engine and to increase the compression ratio, the combustion temperature needs to be addressed and introduction of hollow valves charged with a coolant cannot be avoided.

Accordingly, there is a problem in that a trade-off occurs between the component costs of the intake and exhaust valves and the downsizing of an engine.

In addition, there is a second problem with weight reduction of the intake and exhaust valves.

Metallic sodium is often used as coolant to be charged in a valve. The weight of the valve charged with a coolant is larger than in a hollow valve charged with no coolant as a matter of course, thereby weakening friction reduction effects.

Accordingly, there is another trade-off between the cooling performance and weight reduction of the intake and exhaust valves.

There is another problem with reduction in intake efficiency. Coolant is encapsulated in the intake valve to transfer the temperature of the valve head of a valve to the stem. If the temperature of the stem of the intake valve rises, intake air passing through the stem is heated. When intake air is heated, volume efficiency is reduced and combustion efficiency is reduced.

Accordingly, there is another trade-off between the cooling performance and the volume efficiency of the intake valve.

The invention addresses the above problems with the object of finding compromises in the relationship between the costs of the intake and exhaust valves and the downsizing of an engine and the relationship between the cooling performance and followability/volume efficiency of the intake and exhaust valves and coordinating these conflicting relationships as much as possible.

Solution to Problem

To solve the above problem and achieve the above object, according to the invention, there is provided a cylinder head for an internal combustion engine, the cylinder head including an intake valve having a stem and a valve head and an exhaust valve having a stem and a valve head, in which the intake valve is a hollow valve internally having an internal cavity charged with no coolant and the exhaust valve is a hollow valve internally having an internal cavity charged with a coolant.

The balance between performance and cost can be optimized by using a hollow valve charged with a coolant as the exhaust valve and using a hollow valve charged with no coolant as the intake valve.

The intake valve may be a hollow head valve in which the internal cavity is provided in the stem and the valve head. The weight reduction of the intake valve is enabled by using a hollow head valve as the intake valve.

Alternatively, the intake valve may a hollow stem valve in which the internal cavity is provided in the stem. By using a hollow stem valve as the intake valve, reduction in the strength of the intake valve can be prevented particularly in a valve having a large valve head diameter, consequently ensuring reliability in a high combustion pressure engine. In addition, production cost can be reduced.

In addition, the exhaust valve may be a hollow head valve in which the internal cavity is provided in the stem and the valve head. By using a hollow head valve as the exhaust valve charged with a coolant, coolant can circulate through the valve head, thereby ensuring high cooling effects.

Alternatively, the exhaust valve may be a hollow stem valve in which the internal cavity is provided in the stem. By using a hollow stem valve the exhaust valve, production cost can be reduced.

When the valve head of the intake valve is larger than the valve head of the exhaust valve, the length of the internal cavity of the intake valve may be larger than the length of the internal cavity of the exhaust valve or the diameter of internal cavity of the intake valve may be larger than the diameter of the internal cavity of the exhaust valve. It will be appreciated that the length of the internal cavity of the intake valve may be larger than the length of the internal cavity of the exhaust valve and the diameter of the internal cavity of the intake valve may be larger than the diameter of internal cavity of the exhaust valve. The weight difference between the intake valve and the exhaust valve caused by the difference between the sizes of the valve heads can be reduced by changing either or both of the lengths and the diameters of the internal cavities. This can reduce engine friction and improve the fuel economy of the engine.

An engine according to the invention solves the above problem by including a cylinder block that holds a piston in a reciprocally movable manner in a cylinder and rotatably holds a crankshaft that converts a reciprocating motion of the piston to a rotational motion via a connecting rod and the cylinder head according to any one of the first to seventh aspects, the cylinder communicating with a combustion chamber through the cylinder head, the cylinder head being fixed to the cylinder block.

Advantageous Effects of Invention

According to the invention, a hollow valve charged with a coolant having good cooling function is used as the exhaust valve exposed to a higher temperature environment than the intake valve. In contrast, since a hollow valve that has no coolant, the lightest weight, high followability, and low cost is used as the intake valve which is required further followability, it is possible to provide a cylinder head and an engine having good balance between the cooling performance, the followability, and the costs of the intake and exhaust valves.

BRIEF DESCRIPTION OF DRAWINGS

FIG. **1** is longitudinal sectional view illustrating an engine according to an embodiment.

FIG. **2** is a plan view illustrating intake and exhaust systems of the engine including a turbocharger.

FIG. **3**(*a*) is a longitudinal cross sectional front view illustrating an intake valve and FIG. **3**(*b*) is a longitudinal cross sectional front view illustrating an exhaust valve in a first form of a combination of the intake and exhaust valves.

FIG. **4**(*a*) is a longitudinal cross sectional front view illustrating an intake valve and FIG. **4**(*b*) is a longitudinal cross sectional front view illustrating an exhaust valve in a second form of the combination of the intake and exhaust valves.

FIG. **5**(*a*) is a longitudinal cross sectional front view illustrating an intake valve and FIG. **5**(*b*) is a longitudinal cross sectional front view illustrating an exhaust valve in a third form of the combination of the intake and exhaust valves.

FIG. **6**(*a*) is a longitudinal cross sectional front view illustrating an intake valve and FIG. **6**(*b*) is a longitudinal cross sectional front view illustrating an exhaust valve in a fourth form of the combination of the intake and exhaust valves.

FIG. **7**(*a*) is a longitudinal cross sectional front view illustrating an intake valve and FIG. **7**(*b*) is a longitudinal cross sectional front view illustrating an exhaust valve in a modification of the combination of the intake and exhaust valves.

FIG. **8**(*a*) is a longitudinal cross sectional front view illustrating an intake valve and FIG. **8**(*b*) is a longitudinal cross sectional front view illustrating an exhaust valve in another modification of the combination of the intake and exhaust valves.

FIG. **9**(*a*) is a longitudinal cross sectional front view illustrating an intake valve and FIG. **9**(*b*) is a longitudinal cross sectional front view illustrating an exhaust valve in still another modification of the combination of the intake and exhaust valves.

DESCRIPTION OF EMBODIMENTS

An embodiment will be described with reference to the drawings.

The embodiment is an example of application to the engine having a turbocharger.

The following items will be described.

1. Basic structure of the engine
2. Intake and exhaust systems of the engine
3. Structures of the intake valve and the exhaust valve

(1) First form

(2) Second form

(3) Third form

(4) Fourth form

4. Working effect

(1) Relationship between the component costs of the intake and exhaust valves and the downsizing of the engine

(2) Relationship between the cooling performance and the followability of the intake and exhaust valves

5. Modifications

1. Basic Structure of the Engine

As illustrated in FIG. **1**, an engine **11** includes a cylinder block **201** and a cylinder head **101** mounted thereon.

The cylinder block **201** has a cylinder **211** in an upper part thereof and rotatably holds the crankshaft **221** in a lower part thereof.

The cylinder **211** has a cylindrical shape and slidably houses a piston **231** therein. Accordingly, the piston **231** can perform reciprocating motion while sliding on the inner wall of the cylinder **211** having undergone a smoothing surface process.

The piston **231** as described above is coupled to the crankshaft **221** via a connecting rod **241** so that the reciprocating motion of the piston **231** is converted to the rotational motion of the crankshaft **221** via the connecting rod **241**.

The shaft indicated by reference numeral **222** in FIG. **1** is a rotational shaft of the crankshaft **221**. In addition, the shaft indicated by reference numeral **223** is a coupling shaft of the crankshaft **221** that is connected to the connecting rod **241**.

The cylinder head **101** is coupled to the cylinder block **201** in a position in which the cylinder head **101** faces the cylinder **211** and the piston **231** and a combustion chamber forming region **111** is provided in this coupling part. The combustion chamber forming region **111** is a region that forms a combustion chamber C in the state in which the cylinder head **101** is mounted on the cylinder block **201**, and intake and exhaust ports **121** and **131** and a plug hole **141** to which an ignition plug **301** is attached are opened therein.

In FIG. **1**, the intake port is indicated by the reference numeral **121** and the exhaust port is indicated by the reference numeral **131**. The intake port **121** and the exhaust port **131** are positioned symmetrically with respect to the axial center of the piston **231**, the intake port **121** communicates with the intake passage **122**, and the exhaust port **131** communicates with the exhaust passage **132**.

The plug hole **141** is a threaded hole into which the ignition plug **301** can be screwed and positioned at the axial center of the piston **231**.

The cylinder head **101** has intake and exhaust valves **151** and **161**.

In FIG. **1**, the intake valve is indicated by the reference numeral **151** and the exhaust valve is indicated by the reference numeral **161**. The intake valve **151** and the exhaust valve **161** are slidably held by a valve guide VG attached to the cylinder head **101**.

The intake and exhaust valves **151** and **161** have a fungiform as a whole in which substantially conical valve heads **153** and **163** are coupled one ends of cylindrical stems **152** and **162**. In the following description of this specification, the side close to the stems **152** and **162** of the intake and exhaust valves **151** and **161** is referred to as the upper side and the side close to the valve heads **153** and **163** is referred to as the lower side. The intake and exhaust ports **121** and **131** are opened and closed by the valve heads **153** and **163**. In the intake and exhaust valves **151** and **161** as described above, upper sheets US are attached to the rear ends of the stem **152** and **162**. In the cylinder head **101**, lower sheets LS are formed in positions facing the upper sheet US, and compressed valve springs CS are disposed between the upper sheets US and the lower sheets LS.

Accordingly, when pressing forces are applied to the rear ends, the intake and exhaust valves **151** and **161** slide and move to release the intake and exhaust ports **121** and **131**. Since the upper sheets US come close to the lower sheets LS at this time, the valve springs CS are compressed. When the compression forces applied to the rear ends are released, restoring forces of the compressed valve springs CS bias the intake and exhaust valves **151** and **161** and immediately return the valves **151** and **161** to the original positions.

A valve driving mechanism **171** drives the intake and exhaust valves **151** and **161** and opens and closes the intake and exhaust ports **121** and **131**.

The valve driving mechanism **171** is built into the cylinder head **101** and mainly includes two camshafts **172** that separately drive the intake and exhaust valves **151** and **161**, respectively. These camshafts **172** have cams **173** that apply pressing forces to the rear ends of the intake valve **151** and the exhaust valve **161**, respectively, and the rotation of the camshafts **172** causes the cams **173** to drive the intake valve **151** and the exhaust valve **161** at predetermined timings.

This achieves four-cycle operation including “intake” in which only the intake port **121** is opened, “compression” and “combustion” in which both the intake and exhaust ports **121** and **131** are closed, and “exhaust” in which only the exhaust port **131** is opened.

In the processes of such four-cycle operation described above, the valve driving mechanism **171** synchronizes with the rotation of the crankshaft **221** so that “intake” is performed at the timing at which the piston **231** lowers toward the bottom dead center, “compression” is performed at the timing at which the piston **231** having lowered to the bottom dead center rises to the top dead center, “combustion” is performed at the timing at which the piston **231** has risen to the top dead center, and “exhaust” is performed at the timing at which the piston **231** having lowed to the bottom dead center rises toward the top dead center.

Although not illustrated FIG. **1**, the cylinder head **101** has a fuel injection device (not illustrated). This fuel injection device sprays gasoline, which is fuel, into the combustion chamber C at the timing of “intake” to generate an air-fuel mixture. Accordingly, the air-fuel mixture including fuel is compressed in the “compression” process and the compressed air-fuel mixture explodes due to fire caused by the ignition plug **301** to perform the “combustion” process.

2. Intake and Exhaust Systems of the Engine

As illustrated in FIG. **2**, the engine **11** according to the embodiment is a four-cylinder engine and has a turbocharger **401**.

That is, an intake manifold **411** branched into four piles that form the intake passages **122** for individual cylinders and an exhaust manifold **421** branched into four pipes that form the exhaust passages **132** for the individual cylinders are connected to the cylinder head **101** of the engine **11**. Four pipes **411***a* of the intake manifold **411** are merged to form one collection pipe **411***b* and four pipes **421***a* of the exhaust manifold **421** are merged to form one collection pipe **421***b*.

A turbine **402** of the turbocharger **401** is disposed in the exhaust passage **132** formed by the collection pipe **421***b* of the exhaust manifold **421** merged into one.

A compressor **403** of the turbocharger **401** coupled to the turbine **402** in the same axis is disposed in the intake passage **122** formed by the collection pipe **411***b* of the intake manifold **411** merged into one.

Accordingly, exhaust gas flowing through the exhaust passage **132** rotates the turbine **402** and the compressor **403** thereby rotates at the same speed to compress air. Then, the air-fuel mixture including more oxygen is fed into the combustion chamber C in the “intake” process to improve the combustion efficiency in the “combustion” process.

In the supercharge process by the turbocharger **401** as described above, the temperature of air flowing through the intake passage **122** is raised by compression by the compressor **403**. This easily causes nocking due to the air-fuel mixture captured in the cylinder **211** in the “intake” process. Accordingly, in the embodiment, an intercooler **431** is provided between the compressor **403** and the branch pipes **411***a* to lower the temperature of air flowing through the intake passage **122**.

In addition, a throttle valve **441** is provided downstream of the intercooler **431** in the intake passage **122** so that the flowrate of air flowing through the intake passage **122** can be adjusted.

It will be appreciated that the structures of the above cylinder head and other engine parts are examples and the structures of the intake and exhaust valves described later, which are features of the invention, are widely applicable to a cylinder head of an internal combustion engine or an engine.

3. Structures of the Intake Valve and the Exhaust Valve

In the embodiment, hollow valves are used as the intake valve **151** and the exhaust valve **161**. A hollow valve internally has a internal cavity H.

Although both the intake valve **151** and the exhaust valve **161** have hollow valves, these valves have different structures.

FIGS. **3**(*a*) and **3**(*b*) to FIGS. **6**(*a*) and **6**(*b*) illustrate four examples (first to fourth forms) of the combination of the intake valve **151** and the exhaust valve **161** that can be adopted in the embodiment.

(1) First Form

As illustrated in FIG. **3**(*a*), the internal cavity H of the intake valve **151** is formed as one continuous space extending from the vicinity of the middle of the stem **152** to the valve head **153**. As illustrated, a valve in which not only the stem, but also the valve head is hollow is referred to below as a "hollow head valve". When the valve head is also hollow, the weight of the intake valve **151** can be further reduced and engine friction can be reduced. The intake valve **151**, which is a hollow head valve, charged with no coolant.

Since the process for charging with a coolant in the intake valve is not present as described above, low cost and high performance can be achieved. If the intake valve **151** charged with a coolant, the heat of the valve head **153** is transferred to the stem **152** via coolant and the temperature of the stem **152** may rise. Since no coolant is charged, it is possible to prevent the temperature of intake air from rising due to a rise in the temperature of the stem **152** and prevent reduction in the combustion efficiency.

As illustrated in FIG. **3**(*b*), the exhaust valve **161** is a hollow head valve having the internal cavity H not only in the stem **162**, but also in the valve head **163**. Furthermore, the internal cavity H charged with a coolant **164**. For example, metallic sodium is used as the coolant **164**. Since the exhaust valve **161** is a hollow head valve, the coolant **164** circulates through the valve head **163** and high cooling effects can be obtained. Since the temperature of the bottom surface of the exhaust valve **161** is lowered by the coolant **164**, the intake efficiency can be improved, nock limit can be extended, and preignition can be prevented. In addition, since the temperatures of the valve head **163** and the stem **164** are lowered, the safety ratio in material strength can be improved. As a result, a light and inexpensive valve steel material can be used, thereby improving economical efficiency.

(2) Second Form

In the second form, as illustrated in FIG. **4**(*a*), the intake valve **151** is a hollow head valve having the internal cavity H charged with no coolant as in the first form. In addition, as illustrated in FIG. **4**(*b*), the exhaust valve **161** is a hollow head valve having the internal cavity H also in the valve head **163** and the internal cavity H of the exhaust valve **161** charged with a coolant **164**.

As illustrated in FIG. **4**, the valve head **153** of the intake valve **151** is normally larger than the valve head **163** of the exhaust valve **161**. Accordingly, when the internal cavities H of both valves have the same size as illustrated in FIG. **3**, the intake valve **151** is heavier than the exhaust valve **161**. The exhaust valve **161** charged with the coolant **164** and the specific gravity of coolant **161** is normally smaller than in the valve steel material. For example, the specific gravity of metallic sodium is about one-eighth of that of valve steel material. Accordingly, even if the weight of the coolant **164** is added, the intake valve **151** is normally heavier than the exhaust valve **161**.

As described above, the intake valve **151** and the exhaust valve **161** are biased by the valve springs CS and kept in the closed state. Accordingly, the valve spring CS needs to be designed to generate a reaction force proportional to the weight of the valve. Normally, the valve spring CS common to the intake valve **151** and the exhaust valve **161** is used to reduce the production cost of the component. Accordingly, the valve spring CS is designed so as to correspond to the intake valve **151** having a heavier weight. If the weight difference with the exhaust valve **161** is reduced by weight reduction of the intake valve **151**, the reaction force of the valve spring CS can be reduced. As a result, engine friction can be reduced and the fuel economy of the engine can be improved.

Therefore, as illustrated in FIG. **4**, a length L**1** of the internal cavity H of the intake valve **151** is set to a value larger than a length L**2** of the internal cavity H of the exhaust valve **161**. Here, "the length of the internal cavity" means the length from the lower end of the intake valve **151** or the exhaust valve **161** to the upper end of the internal cavity H. If the internal cavity H of the intake valve **151** is extended as described above, the volume of the internal cavity H is increased, thereby reducing the amount of valve steel material. Accordingly, the weight difference with the exhaust valve **161** can be reduced by weight reduction of the intake valve **151**. Since the length L**1** and the length L**2** are not limited to particular values, they can be set to appropriate values so that the weight difference between the intake valve **151** and the exhaust valve **161** is reduced or the weights of these valves are identical.

(3) Third Form

In the third form, as illustrated in FIG. **5**(*b*), the exhaust valve **161** is a hollow head valve having the internal cavity H not only in the stem **162**, but also in the valve head **163** as in the first and second forms and charged with the coolant **164** therein.

In addition, in the third form, the intake valve **151** has the internal cavity H only in the stem **152** and the valve head **153** is solid as illustrated in FIG. **5**(*a*). A valve having the internal cavity H only in the stem **152** as described above is referred to as a "hollow stem valve".

In a high combustion pressure engine, particularly in the case of a hollow head valve having a large valve head diameter, when a hollow head valve is used as the intake valve, the bottom surface may be bowed. Accordingly, when a hollow stem valve is used as the intake valve **151** consciously, reliability can be obtained by preventing reduction in strength. In addition, when a hollow stem valve is used, the production cost can be reduced.

In contrast, since the valve head of a hollow stem valve is solid, a hollow stem valve is heavier than a hollow head valve. Since the exhaust valve **161** is a hollow head valve in the third form, the weight difference between both valves is larger than in the second form. Therefore, when the length of an internal cavity L**1** of the intake valve **151** becomes further larger than in the second form as illustrated in FIG. **5**, the weight of the intake valve **151** can be further reduced and the weight difference with the exhaust valve **161** can be reduced. This can reduce engine friction and improve the fuel economy of the engine as in the second form.

(4) Fourth Form

As illustrated in FIG. **6**(*a*), the intake valve **151** is a hollow stem valve having the internal cavity H only in the stem **152** as in the third form.

As illustrated in FIG. **6**(*b*), the exhaust valve **161** in the fourth form is the same as the exhaust valves **161** in the first to third forms. That is, the exhaust valve **161** in the fourth form is a hollow head valve having the internal cavity H not only in the stem **162**, but also in the valve head **163** and charged with the coolant **164** therein.

In the fourth form, the internal cavities Hof the intake valve **151** and the exhaust valve **161** have the same length and a diameter D**1** of the internal cavity H of the intake valve **151** is larger than a diameter D**2** of the internal cavity of the exhaust valve **161**. When the diameter D**1** of the internal cavity H of the intake valve **151** is increased, the volume of the internal cavity H is increased and the amount of valve steel material is reduced by that volume. This can reduce the weight difference between the intake valve **151** and the exhaust valve **161** by weight reduction of the intake valve **151** as in the second and third forms. As a result, engine friction can be reduced and the fuel economy of the engine can be improved. It should be noted here that "the diameter of the internal cavity" means the diameter of the stem of the internal cavity. Since the diameter D**1** and the diameter D**2** are not limited to particular values, they can be set to appropriate values so that the weight difference between the intake valve **151** and the exhaust valve **161** is reduced or the weights of these valves are identical.

4. Working Effect

Since the working effects of the engine **11** and the turbocharger **401** have been simply described above, detailed descriptions are omitted.

Here, the working effects of the intake and exhaust valves **151** and **161** will be described.

(1) Relationship Between the Component Costs of the Intake and Exhaust Valves and the Downsizing of the Engine

Adoption of a hollow valve charged with the coolant is preferable to achieve the downsizing of the engine as described above and it is necessary in some cases.

However, since a hollow valve charged with the coolant is much more expensive in component cost than that of a solid valve, such a hollow valve cannot be unconditionally adopted regardless of the type and grade of a vehicle.

Accordingly, optimum combinations of the intake and exhaust valves **151** and **161** are proposed in the embodiment.

First, when attention is focused on the difference between environments to which the intake valve **151** and the exhaust valve **161** are exposed, severer heat measures need to betaken for the exhaust valve **161**. This is because the exhaust valve **161** is exposed to a higher temperature environment to introduce combustion gas heated by combustion from the exhaust port **131** to the exhaust passage **132** than the intake valve **151**, which only needs to capture outside air from the intake port **121** to the cylinder **211**.

Therefor, in the embodiment, as described above first form to third form a hollow valve charged with the coolant is used as the exhaust valve **161** and a hollow valve charged with no coolant is used as the intake valve **151**.

This can coordinate these conflicting relationships between the component costs of the intake and exhaust valves **151** and **161** and the downsizing of the engine **11** as much as possible.

(2) Relationship Between the Cooling Performance and the Followability of the Intake and Exhaust Valves

The improvement of combustion efficiency in the combustion chamber C and the higher revolution of the engine are significantly effected by the followability of the intake and exhaust valves **151** and **161**.

For example, when the followability of the intake valve **151** is poor, the amount of air-fuel mixture that can be introduced into the cylinder **211** in the "intake" process fluctuates. This is because the maximum amount of air-fuel mixture may not be introduced to the cylinder **211** or the introduced air-fuel mixture may be returned through the intake port **121** when the followability of the intake valve **151** is poor.

Similarly, when the followability of the exhaust valve **161** is poor, there is a problem in that gas resulting from combustion remains in the combustion chamber C.

Therefore, in the embodiment, hollow valves are adopted as the intake and exhaust valves **151** and **161** to improve the followability.

Since a hollow valve charged with no coolant **164** is used especially for the intake valve **151**, further improvement of the followability can be expected.

5. Modifications

Although an embodiment of the invention has been described above, various omissions, replacements, and changes can be made without departing from the spirit of the invention. The above embodiment and the modifications thereof are included in the scope and spirit of the invention and included in the invention designated in the appended claims and the equivalent scope.

For example, although the examples (the second and third forms described above) in which the length L**1** of the internal cavity H of the intake valve **151** is larger than the length L**2** of the internal cavity H of the exhaust valve **161** and the example (the fourth form described above) in which the diameter D**1** of the internal cavity H of the intake valve **151** is larger than the diameter D**2** of the internal cavity H of the exhaust valve **161** are illustrated in the above embodiment, these two means may be used together in practice.

In addition, although the example in which a hollow stem valve is used as the intake valve **151** is illustrated in the fourth form, a hollow head valve may be used as the intake valve **151** and the diameter D**1** of the internal cavity H may be larger than the diameter D**2** of the internal cavity H of the exhaust valve **161**.

In addition, a hollow head valves are used as the exhaust valves **161** in the above forms as an example. However, a hollow stem valve may be used as the exhaust valve **161** as illustrated in FIG. **8**(*b*) and FIG. **9**(*b*). By using a hollow stem valve as the exhaust valve **161**, the production cost can be reduced. In this case, a hollow stem valve may be used as the intake valve **151** as illustrated in FIG. **8**(*a*) or a hollow head valve may be used as illustrated in FIG. **9**(*a*). In the cases of FIG. **8** and FIG. **9**, when there is a weight difference between the intake valve **151** and the exhaust valve **161**, this weight difference may be reduced by making the length L**1** of the internal cavity H of the intake valve **151** larger than the length L**2** of the internal cavity H of the exhaust valve **161** or making the diameter D**1** larger than the diameter D**2**.

Although the intake valve **151** is normally heavier than the exhaust valve **161** as described above, if the exhaust valve **161** is heavier than the intake valve **151**, the length L**2** of the internal cavity H of the exhaust valve **161** may be larger than the length L**1** of the internal cavity H of the intake valve **151** or the diameter D**2** may be larger than the diameter D**1**.

Any other modifications and changes are allowed.

REFERENCE SIGNS LIST

111: combustion chamber forming region
121: intake port
131: exhaust port
151: intake valve
161: exhaust valve
171: valve driving mechanism
201: cylinder block
211: cylinder
221: crankshaft
231: piston
241: connecting rod
C: combustion chamber
H: internal cavity

The invention claimed is:

1. A cylinder head for an internal combustion engine, the cylinder head comprising:
an intake valve having a stem and a valve head; and
an exhaust valve having a stem and a valve head,
wherein the intake valve is a hollow valve internally having an internal cavity charged with no coolant and the exhaust valve is a hollow valve internally having an internal cavity charged with a coolant.

2. The cylinder head according to claim **1**,
wherein the intake valve is a hollow head valve in which the internal cavity is provided in the stem and the valve head.

3. The cylinder head according to claim **2**,
wherein the exhaust valve is a hollow head valve in which the internal cavity is provided in the stem and the valve head.

4. The cylinder head according to claim **3**,
wherein the diameter of the valve head of the intake valve is larger than the diameter of the valve head of the exhaust valve and the length of the internal cavity of the intake valve is larger than the length of the internal cavity of the exhaust valve.

5. The cylinder head according to claim **3**,
wherein the diameter of the valve head of the intake valve is larger than the diameter of the valve head of the exhaust valve and the diameter of the internal cavity of the intake valve is larger than the diameter of the internal cavity of the exhaust valve.

6. An engine comprising:
a cylinder block that holds a piston in a reciprocally movable manner in a cylinder and rotatably holds a crankshaft that converts a reciprocating motion of the piston to a rotational motion via a connecting rod; and
the cylinder head according to claim **3**, the cylinder communicating with a combustion chamber through the cylinder head, the cylinder head being fixed to the cylinder block.

7. The cylinder head according to claim **2**,
wherein the exhaust valve is a hollow stem valve in which the internal cavity is provided in the stem.

8. The cylinder head according to claim **7**,
wherein the diameter of the valve head of the intake valve is larger than the diameter of the valve head of the exhaust valve and the length of the internal cavity of the intake valve is larger than the length of the internal cavity of the exhaust valve.

9. The cylinder head according to claim **2**,
wherein the diameter of the valve head of the intake valve is larger than the diameter of the valve head of the exhaust valve and the length of the internal cavity of the intake valve is larger than the length of the internal cavity of the exhaust valve.

10. The cylinder head according to claim **2**,
wherein the diameter of the valve head of the intake valve is larger than the diameter of the valve head of the exhaust valve and the diameter of the internal cavity of the intake valve is larger than the diameter of the internal cavity of the exhaust valve.

11. An engine comprising:
a cylinder block that holds a piston in a reciprocally movable manner in a cylinder and rotatably holds a crankshaft that converts a reciprocating motion of the piston to a rotational motion via a connecting rod; and
the cylinder head according to claim **2**, the cylinder communicating with a combustion chamber through the cylinder head, the cylinder head being fixed to the cylinder block.

12. The cylinder head according to claim **1**,
wherein the intake valve is a hollow stem valve in which the internal cavity is provided in the stem.

13. The cylinder head according to claim **12**,
wherein the exhaust valve is a hollow head valve in which the internal cavity is provided in the stem and the valve head.

14. The cylinder head according to claim **12**,
wherein the exhaust valve is a hollow stem valve in which the internal cavity is provided in the stem.

15. The cylinder head according to claim **12**
wherein the diameter of the valve head of the intake valve is larger than the diameter of the valve head of the exhaust valve and the length of the internal cavity of the intake valve is larger than the length of the internal cavity of the exhaust valve.

16. The cylinder head according to claim **12**,
wherein the diameter of the valve head of the intake valve is larger than the diameter of the valve head of the exhaust valve and the diameter of the internal cavity of the intake valve is larger than the diameter of the internal cavity of the exhaust valve.

17. An engine comprising:
a cylinder block that holds a piston in a reciprocally movable manner in a cylinder and rotatably holds a crankshaft that converts a reciprocating motion of the piston to a rotational motion via a connecting rod; and
the cylinder head according to claim **12**, the cylinder communicating with a combustion chamber through the cylinder head, the cylinder head being fixed to the cylinder block.

18. The cylinder head according to claim **1**,
wherein the diameter of the valve head of the intake valve is larger than the diameter of the valve head of the exhaust valve and the length of the internal cavity of the intake valve is larger than the length of the internal cavity of the exhaust valve.

19. The cylinder head according to claim **1**,
wherein the diameter of the valve head of the intake valve is larger than the diameter of the valve head of the exhaust valve and the diameter of the internal cavity of the intake valve is larger than the diameter of the internal cavity of the exhaust valve.

20. An engine comprising:
a cylinder block that holds a piston in a reciprocally movable manner in a cylinder and rotatably holds a crankshaft that converts a reciprocating motion of the piston to a rotational motion via a connecting rod; and

the cylinder head according to claim **1**, the cylinder communicating with a combustion chamber through the cylinder head, the cylinder head being fixed to the cylinder block.

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